

ANSWERS: pH and pKa

1. Hydrofluoric acid is a stronger acid/more acidic/dissociates more because it has a smaller pK_a (larger K_a) than hypochlorous acid.

So HF will therefore have a higher $[H_3O^+]$. As $[H_3O^+]$ increases, the pH decreases, so HF will have a lower pH than HOCl.

(pH HF = 2.09, HOCl = 4.27)

2.

$$[H_3O^+] = 10^{-11.8} = 1.58 \times 10^{-12}$$

$$K_a = \frac{[CH_3NH_2][H_3O^+]}{[CH_3NH_3^+]} \\ = \frac{[CH_3NH_2][H_3O^+]}{[OH^-]}$$

$$2.29 \times 10^{-11} = \frac{[CH_3NH_2] \cdot (10^{-11.8})^2}{1 \cdot 10^{-14}}$$

$$[CH_3NH_2] = \frac{(2.29 \cdot 10^{-11}) \cdot (1 \cdot 10^{-14})}{(10^{-11.8})^2}$$

$$= 0.0912 \text{ mol L}^{-1}$$

OR

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{10^{-14}}{10^{-11.8}} \\ = 6.31 \times 10^{-3} \text{ mol L}^{-1}$$

$$K_b = \frac{[OH^-]^2}{[CH_3NH_2]}$$

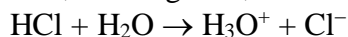
$$4.37 \times 10^{-4} = \frac{(6.31 \cdot 10^{-3})^2}{[CH_3NH_2]}$$

$$[CH_3NH_2] = \frac{(6.31 \cdot 10^{-3})^2}{4.37 \cdot 10^{-4}}$$

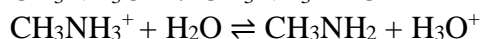
$$[CH_3NH_2] = 0.0912 \text{ mol L}^{-1}$$

3. a) $HCl < CH_3NH_3Cl < CH_3NH_2$

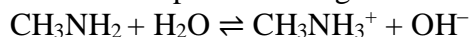
HCl, a strong acid, reacts completely with water to form $1 \text{ mol L}^{-1} H_3O^+$ and hence a low pH.



CH_3NH_3Cl dissociates completely in water to form $CH_3NH_3^+$ and Cl^- . $CH_3NH_3^+$, a weak acid, partially reacts with water to form less than $1 \text{ mol L}^{-1} H_3O^+$ and hence a higher pH than HCl.



CH_3NH_2 , a weak base, partially reacts with water to form OH^- ions. So there are more OH^- ions than H_3O^+ ions and the pH is thus high.



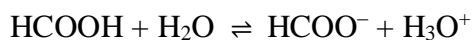
4.

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} \quad \bullet \quad pH = pK_a + \log \frac{[base]}{[acid]}$$

$$[H_3O^+] = \sqrt{1.74 \cdot 10^{-5} \cdot 0.0896 \text{ mol L}^{-1}} \\ = 1.25 \cdot 10^{-3} \text{ mol L}^{-1}$$

$$pH = -\log[H_3O^+] = 2.90$$

5.

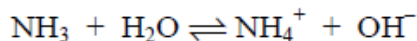


$$K_a = \frac{[\text{HCOO}^-][\text{H}_3\text{O}^+]}{[\text{HCOOH}]}$$

$$10^{-3.74} = \frac{(10^{-2.78})^2}{[\text{HCOOH}]}$$

$$[\text{HCOOH}] = 0.0151 \text{ mol L}^{-1}$$

6.



$$K_a = 10^{-9.24} = 5.75 \times 10^{-10}$$

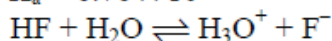
$$K_b = [\text{OH}^-]^2 / [\text{NH}_3] = K_w / K_a = 1.74 \times 10^{-5}$$

$$[\text{OH}^-] = \sqrt{(1.74 \times 10^{-5} \times 0.150)} = 1.61 \times 10^{-3} \text{ mol L}^{-1}$$

$$[\text{H}_3\text{O}^+] = K_w / [\text{OH}^-] = 6.19 \times 10^{-12} \text{ mol L}^{-1} \quad \text{pH} = 11.2$$

7)

$$K_a = 6.76 \times 10^{-4}$$



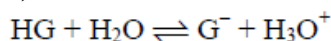
$$\text{Assume } [\text{H}_3\text{O}^+] = [\text{F}^-]$$

$$K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{HF}]} \Rightarrow [\text{HF}] = \frac{[\text{H}_3\text{O}^+]^2}{K_a}$$

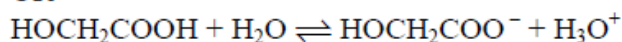
$$[\text{H}_3\text{O}^+] = 4.57 \times 10^{-3} \text{ mol L}^{-1}$$

$$[\text{HF}] = 0.0309 \text{ mol L}^{-1}$$

8)



OR



$$K_a = \frac{[\text{G}^-][\text{H}_3\text{O}^+]}{[\text{HG}]} \quad (\text{must have equilibrium arrow})$$

$$[\text{H}_3\text{O}^+] = \sqrt{K_a} \times [\text{HG}]$$

$$K_a = 1.50 \times 10^{-4}$$

$$[\text{H}_3\text{O}^+] = 9.99 \times 10^{-3} \text{ mol L}^{-1}$$

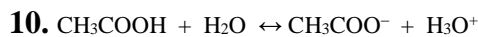
$$\text{pH} = 2.00$$

9)

$$K_a = \frac{[\text{NH}_3][\text{H}_3\text{O}^+]}{[\text{NH}_4^+]}$$

$$[\text{NH}_4^+] = \frac{[\text{H}_3\text{O}^+]^2}{K_a} = \frac{(10^{-4.66})^2}{10^{-9.24}}$$

$$= \frac{(2.19 \times 10^{-5})^2}{5.75 \times 10^{-10}} = 0.832 \text{ mol L}^{-1}$$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

$$K_a = 1.74 \times 10^{-5}$$

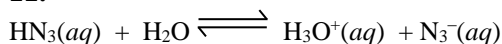
$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]}$$

$$1.74 \times 10^{-5} = \frac{[\text{H}_3\text{O}^+]}{0.0500}$$

$$[\text{H}_3\text{O}^+] = 9.32 \times 10^{-4}$$

$$\text{pH} = -\log(9.32 \times 10^{-4}) = 3.03$$

11.



$$K_a(\text{CH}_3\text{COOH}) = \frac{[\text{H}_3\text{O}^+][\text{N}_3^-]}{[\text{HN}_3]}$$

$$\text{pH} = 2.6 \text{ so } [\text{H}_3\text{O}^+(aq)] = 2.51 \times 10^{-3} \text{ mol L}^{-1} = [\text{N}_3^-(aq)]$$

$$\text{p}K_a(\text{HN}_3) = 4.72, K_a(\text{HN}_3) = 1.91 \times 10^{-5}$$

$$K_a(\text{HN}_3) = 1.91 \times 10^{-5} = \frac{(2.51 \times 10^{-3})^2}{x}$$

$$x = 0.331 \text{ ie } [\text{HN}_3(aq)] = 0.331 \text{ mol L}^{-1} \quad (\text{Allow } 0.330 \text{ and } 0.33)$$

12.

$$K_a(\text{HOBr}) = \frac{[\text{H}_3\text{O}^+][\text{OBr}^-]}{[\text{HOBr}]} = 10^{-8.62} = 2.40 \times 10^{-9}$$

$$[\text{H}_3\text{O}^+(aq)] = [\text{OBr}^-(aq)] = x \text{ mol L}^{-1}$$

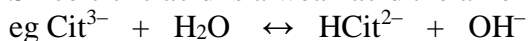
$$\frac{x^2}{0.0525} = 2.40 \times 10^{-9} \quad x = [\text{H}_3\text{O}^+(aq)] = 1.12 \times 10^{-5}$$

$$\text{pH} = 4.95 \quad (\text{allow } 4.9 \text{ or } 4.950)$$

13.

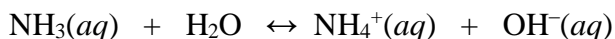
pH greater than 7.

Since citric acid is a weak acid the anion is weakly basic and will react with water to accept H^+ from water.



Increase in $[\text{OH}^-]$ causes increase in pH.

14.



As NH_4Cl dissolves $[\text{NH}_4^+]$ is increased. This causes the equilibrium to move to favour formation of reactants so that $[\text{OH}^-]$ is decreased. As $[\text{OH}^-]$ is decreased, $[\text{H}_3\text{O}^+]$ is increased and pH is decreased.